A Scientometric Map of Global Educational Research

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Abstract: Educational research covers a diverse area of topics that presents integration challenges. We used a bibliographic analysis of the Scopus database to describe educational research and present a global map that consists of 18 research clusters that are connected by distinct sets of references. Clusters differ in their core references and how much they focus on educational research. Some clusters share references in a highly connected way and focus directly on teaching and learning (e.g. Learning cluster) while other clusters share references more loosely and focus on topics that lie at the interaction of education and other related fields (e.g. Sociology of Education cluster). As such, clusters represent subfields of educational research that are differentially organized around different research topics and incorporate shared knowledge bases embodied in shared references. Students, researchers, and practitioners can use our results to explore the collectively built knowledge bases of educational research.

Keywords: educational research, bibliographic coupling analysis, scientometrics

Introduction

Scientometrics, the science of scientific publications, is a field of research that uses various metrics of science to understand the development of sciences and scientific practices (Mingers & Leydesdorff, 2015). In this paper, we use scientometrics to understand the overall map of educational research and in particular, our method uses citation patterns. We know that research publications are connected through citations. In a sense, citations can be seen as an 'uptake' of a contribution made to the community knowledge, similar to the uptake process that occur in the discourse of group interaction (Suthers, Dwyer, Medina, & Vatrapu, 2010). When a reference is cited, it is 'grounded' in the collective knowledge construction activity and connected to the rest of the work in the shared knowledge base, akin to the grounding process that occurs in conversation (Clark, 1996), although the quality of this grounding process varies greatly. Indeed, an individual research contribution, no matter how insightful or high quality it may be, only becomes valuable when it is integrated with the rest of the work in the community (Rosé & Lund, 2013). Through analyses of the field of behavioral research, Longino (2013) was able to conclude that the set of references cited by a paper is very specific to the different disciplines and communities of readership for which the research is meant and that not much citation occurs across users of particular approaches. This result argues for the expression "Tell me who you cite, I will tell you to which subfield you belong", a very general truth that lies at the heart of scientometrics.. In this paper, we examined citation patterns in educational research to reveal a subset of subfields within research in education, for the period studied.

Previous scientometric studies in education

Much of the previous research that used scientometrics in education has looked at particular sub-disciplines for various reasons. For example, (Kirby, Hoadley, & Carr-Chellman, 2005) explored the relationship between Learning Sciences and Instructional Systems Design through a citation analysis of six journals, three in each field. Their analysis showed that the amount of cross-field citation was low at that time, although there was a trend for increased cross-field citation and that this trend was led by a small number of prominent researchers in both communities. On the basis of a qualitative analysis, the authors argued that combining the strengths of both communities—cognition in context on the one hand (Learning Sciences) and design (Instructional Systems Design) on the other—would give researchers a better chance of "effecting meaningful change in education through the creation and effective application of technology-enhanced learning environments" (op. cit., p. 46).

Kienle and Wessner (2006) explored the growth of the field of Computer Supported Collaborative Learning (CSCL) by analyzing ten years of international CSCL conferences (1995-2005). They performed a mixed-method analysis of both quantitative approaches (citation and co-authorship analyses coupled with analysis of conference participant lists and program committees) and qualitative approaches (questionnaire). Results showed that only a small core group of people had participated continuously in the community, yet participation at that time was increasingly international and the international connectivity of the community was also increasing. Alternatively, Tang, Tsai, and Lin (2014) analyzed the emergent thematic structure of the CSCL field using over one thousand leading journal and conference papers indexed in the Web of Science from 2006 to 2013. Results identified six research streams (1) representation, discourse and pattern, (2) factors influencing CSCL, (3) intervention and comparison, (4) critical reasoning, (5) process of social construction, and (6) design and modeling of CSCL. In addition, 56 out of 66 core papers were found in the first three streams and these streams can thus be regarded as most focal.

Each of these three papers (Kienle & Wessner, 2006; Kirby et al., 2005; Tang et al., 2014) focused on a particular sub-discipline of research in education: the Learning Sciences and Instructional Systems Design on the one hand and Computer Supported Collaborative Learning on the other, and focused either on knowledge bases of these communities or the people that create them. In this paper, our goals are similar, yet our focus extends to a more general description of research in education, as revealed by the Scopus database. We are interested in characterizing the bibliographic clustering of educational research papers more generally and in analyzing the extent to which each of these clusters correspond to subfields in educational research.

Methods

In this section, we first describe database selection and data extraction. Second, we describe the concept of bibliographic coupling (BC) and how we constructed the clusters network in the field of education.

Database selection and extraction

There are a number of electronic databases that index academic publications. They all provide wide coverage of selected academic publications and are practical to use. We chose to use Scopus. It has a similar overall coverage as the Web of Science, but a slightly wider coverage of non-English journals. Publication sources in Scopus are classified under four broad subjects categories (Life Sciences, Physical Sciences, Health Sciences and Social Sciences & Humanities) which are further divided into 27 subject areas. The Scopus web interface does not provide a subject category corresponding to educational research. In order to select a corpus of publications in educational research, we relied on a list of educational research publication sources provided by AERES (AERES, 2014), the French national agency for the evaluation of research and higher education, which was in turn based on the European Educational research Quality Indicator (or EERQI) project (http://www.eerqi.eu/).

For the Education corpus studied in this paper, we saved the full records of the documents: authors, names of publication source, years of publication, publication titles, keywords (given by the authors and/or Scopus), and the lists of references included in the publications. In this initial work, we only looked at publications from 2000-2004 since after that time there was a great increase in both the number of journals published and accepted into the Scopus database. Similar work is currently in progress on more recent publications as well as work concerning the evolution of research in education. From the references lists, we additionally extracted authors, year of publication, and title of the reference. References were not always formatted consistently throughout all the records in Scopus (e.g., use of different abbreviations and/or inclusion of subtitles) and/or included missing information (e.g. final publication year of pre-print papers). All in all, around 2% of the references were wrongly formatted.

In total, the extracted Education corpus contains 36,715 bibliographic records. Publications are mainly written in English (94%) by authors from the United States (44%) followed by the United Kingdom (14%), and Australia (5%). The full records are available upon request.[1]

The top two contributing sources in this Education Corpus deal with chemical and medical education (Journal of Chemical Education, Medical Education). The next three contain two professional magazines (Educational Leadership, Phi Delta Kappan) and a source on research in child development (Child Development). Many of the other sources in the list also deal with domain-related education (science, general engineering, electrical engineering, computer engineering, biochemical and molecular biology). The second type of source focuses on the teaching of different domains (medical, English, psychology). The two remaining journals focus on general issues pertaining to education (Journal of Educational Psychology) and on issues affecting the developers of educational systems and educators who implement and manage such systems (Educational Technology & Society).

Bibliographic coupling and construction of network clusters

In order to determine how different papers are linked through common references we systematically compared the reference lists of two publications and identified shared references. Articles are linked if they share at least two references, leading to a network of papers connected to each other. The resulting network is schematically represented in Figure 1a where nodes represent individual papers. The thicker the link, the more references are shared between the papers. The links are weighted by Kessler's (1963) cosine similarity

$$\omega_{ij} = \frac{|R_i \cap R_j|}{\sqrt{|R_i||R_j|}}$$

where R_i is the set of references of article i. By definition, the cosine similarity is equal to zero when two articles do not share any reference and is equal to 1 when their sets of references are identical.

Clusters are then detected using modularity maximization (Newman & Girvan, 2004) and the fast Louvain Algorithm (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008). Modularity quantifies the possibility to split a network into clusters in such a way that the links between nodes (i.e., papers) are dense inside clusters but not between them. There are many techniques available for clustering the nodes of a graph into relevant 'communities' (for a review, see Fortunato, 2010). Thanks to its conceptual simplicity and easiness of computation, modularity is by far the most popular, even if its results should be interpreted with care (Good, de Montjoye, & Clauset, 2010). In previous work on similar bibliographic networks (Grauwin & Jensen, 2011; Grauwin et al., 2012), we have shown that the clusters obtained by modularity maximization do indeed represent the scientific structure of research in a meaningful way.

An example of the resulting cluster membership of each node is represented by different colors in Figure 1. Note that papers belonging to the same cluster (e.g., node 1 and 5 or node 12 and 15) are not always linked directly. Note also that articles belonging to different clusters may share links. The Louvain method detect clusters of nodes so that the number of 'external' connections is as small as possible. In the networks studied in this paper, more than 70% of the links of a paper are with papers belonging to the same cluster.

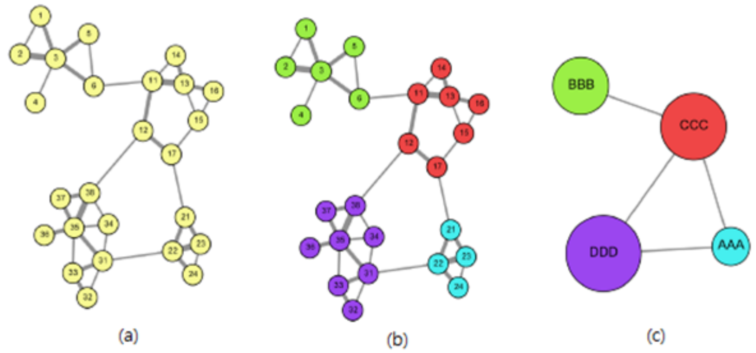

Figure 1. Cluster detection process

Results: Subfields in educational research between 2000-2004

This section illustrates the results and interpretation of our scientometric analyses of the Scopus database from 2000-2004: 1) we first present the main clusters resulting from the bibliographic coupling analysis on the "Education" corpus, 2) we next illustrate the nature of the most cited references of three of the clusters, and 3) we examine the connectivity of these clusters, distinguishing five highly connected clusters, for which education is the central focus, from more loosely connected clusters, which focus on education as well as on other topics.

Main clusters resulting from the bibliographic coupling analysis

We applied the cluster detection algorithm to the 36,715 records in this Education corpus. 22,058 of them shared at least two references with other records in the corpus and are thus included in the final cluster network. Table 1 presents the 18 resulting clusters having at least 400 articles. In order to give the clusters meaningful labels, we examined the most shared references as well as the most used title words and keywords of the clusters' articles. These labels illustrate that each cluster focuses on different aspects of education while relying on specific sets of shared references. Some clusters center on teaching a subject such as mathematics, science, or language. Others focus on underlying learning mechanisms such as motivation and cognitive development in children. Yet others work on larger societal issues such as educational equity and impact. The diversity of the research topics covered by different clusters explains, at least partly, why educational research draws on multiple sets of references. This subset of topics shows that fully understanding research in education, requires not only being concerned with the subjects of teaching, and with the fundamental mechanisms of learning and development, but also with social, historical, political, economical and technical issues.

Table 1. The eighteen main bibliographic clusters of educational research

Clusters sorted by size	N	Clusters sorted by size	N
Learning	1,883	Cognitive Studies of Learning	790
Educational Equality	1,800	Evaluation & Assessment	733
Sociology of Education	1,715	Math Education	685
Child Behavioral Development	1,534	Language Teaching Methods	675
Motivation	1,514	Developmental Disabilities	667
Science Education	1,370	Measurement	648
Higher Education	1,207	Cooperative Learning	554
Reading Education	1,140	Civic Education	417
Teacher Training	799	Child Cognitive Development	415

The nature of the top cited references in three clusters

We examined the nature of the top cited references more closely in three clusters (i.e., Learning, Evaluation and Assessment, and Measurement). The first two authors coded their top twenty references (cf. Table 2 for the first five), according to whether they were (1) theoretical, (2) methodological (e.g., statistics techniques), (3) empirical investigations, (4) disciplinary knowledge sources (e.g., physics textbook) or (5) documents that reflected the consensus of the experts and/or practitioners in the communities (e.g., curriculum and evaluation standards for schools mathematics, publication guidelines). The coding judgment was made based our familiarity with the literature in education and on the title and/or abstracts of the papers.

Table 2. The top five most cited references of the three chosen clusters, full citations are in our references

Learning	Evaluation & Assessment	Measurement
Lave & Wenger, 1991	Marton & Säljö, 1976	Wilkinson, 1999
Vygotsky, 1978	Ramsden, 1992	Lord, 1980
Brown, Collins, & Duguid, 1989	Entwistle & Ramsden, 1983	Standards for educational and psychological testing, 1999
Wenger, 1998	Higher education in the learning society, 1997	Lord, 1968
Rogoff, 1990	Biggs, 1999	Thompson & Vacha-Haase, 2000

Agreement was high (92.5%). The few disagreements involved hesitating between qualifying a few papers in that opinions differed as to the extent of the theoretical contribution, weighed against the empirical.

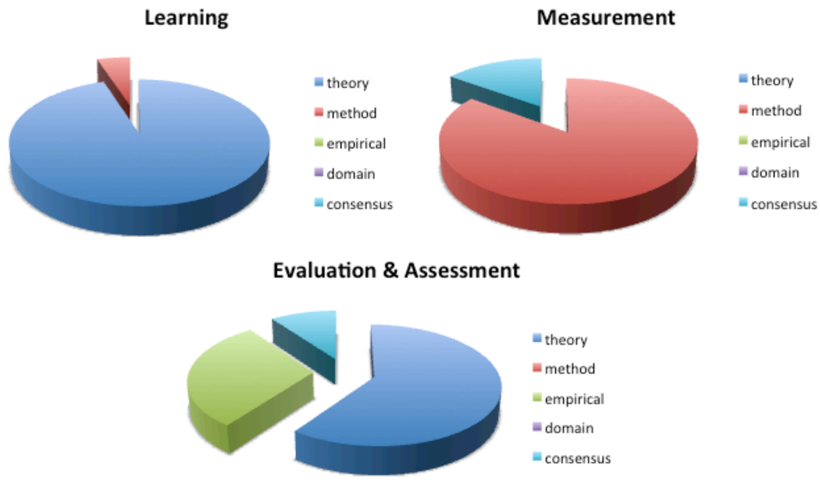

Figure 2. A comparison of the nature of the top twenty cited references of three clusters

As in shown in Figure 2, what connects the papers together in the Learning cluster, was a commitment to theories, mostly socio-cultural theories such as Lave and Wenger (1991) and Vygotsky (1978). On the other hand, in the measurement cluster, references on methods (e.g., item response theory) and consensus (e.g., standards for educational and psychological testing) play an important role. Finally, in the Evaluation and Assessment cluster, most references are general theoretical references about learning, followed by empirical work and consensus documents. Clusters rarely overlap in terms of their core references, that is, in their top 20 references. For example, Vygotsky (1978) and Lave and Wenger (1991) are the top two most cited references across all the clusters, but made the core list in only one of these clusters (i.e., "Learning" cluster).

The connectivity of the clusters

In this section, we show how the different clusters are interlinked. The thickness of an edge between two clusters in Figure 3 is proportional to the extent to which they share the same references, that is, the average weight (W) between articles of both clusters. Note that this link *between* clusters arises mostly from shared references that are not within the clusters' core references (i.e. the top 20 cited).

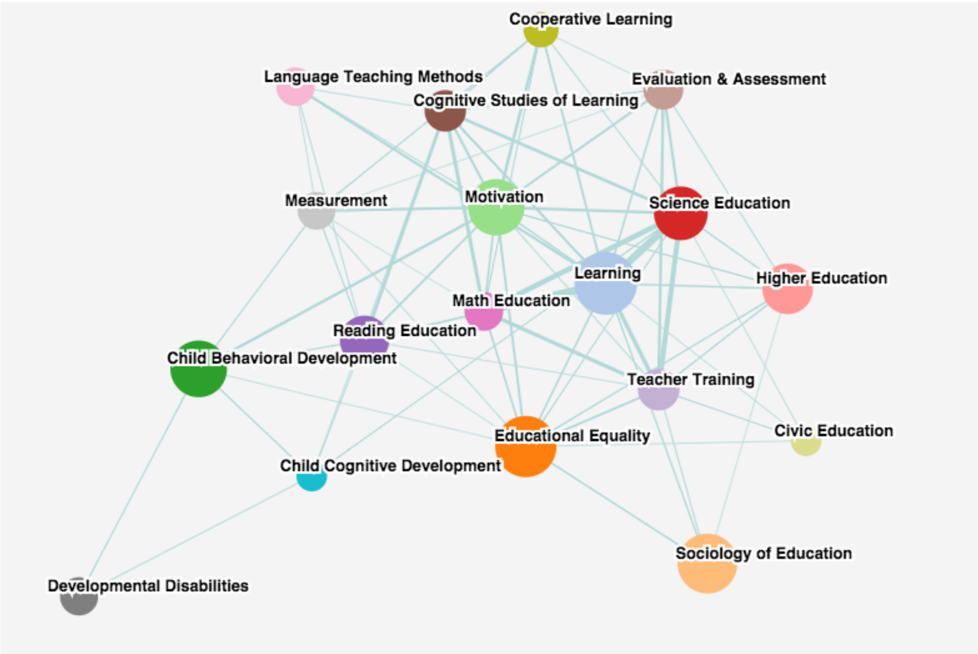

Figure 3. A map showing the different clusters of research in Education from 2000-2004

Summing up the weight (W) of all edges of the cluster pairs, one obtains the weighted degree of a cluster, a "centrality" measure in the language of network theory, which indicates the overall connectivity of the cluster (cf. Table 3). Clusters with a high W value share more references with other clusters than clusters with low W values which use more specialized references. The layout algorithm tends to position highly connected clusters at the center of the map and less connected clusters on the periphery of the map (cf. Figure 3). Clusters also differ in terms of internal modularity Qi, a characterization of their internal 'heterogeneity' (cf. Table 3). Low values of Qi correspond to clusters consisting of papers that are homogeneously interlinked (e.g., "Learning"), which also means that most articles share similar core references (c.f. Figure 4a). For example, the two most cited references of "Learning" are cited by large fractions of its articles (respectively 19% for Lave & Wenger, 1991 and 12% for Vygotsky, 1978). High values of Qi correspond to clusters consisting of papers that are heterogeneously linked (e.g. Sociology of Education). Such clusters have multiple sub-groupings of articles that share similar core references. For example, the "Sociology of Education" cluster (cf. Figure 4b) is composed of several sub-clusters of articles linked by rather distinct sets of references. This can be seen by the much lower citation frequency of the two most cited references of this cluster (5% for Gewirtz, Ball, & Bowe, 1995, and 4% for Oliver, 1996).

The top five highly connected clusters ("Learning", "Motivation", "Science Education", "Math Education" and "Teacher Training") tend to be organized around references that connect the whole network. These clusters appear to focus on teaching and learning directly, either in terms of theoretical approaches to education (e.g., socio-constructivist view), of teacher and student attitudes and identity, or classroom practices. The focus can also be more specific (e.g. math and science teaching/learning practices).

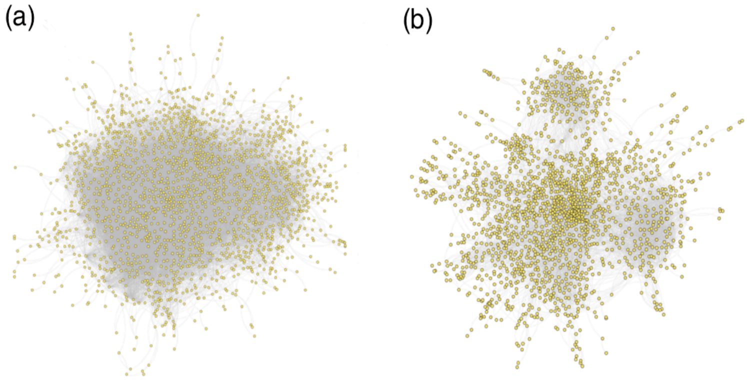

Figure 4. An illustration of the difference between homogenously (a) and heterogeneously (b) linked clusters

Table 3. Clusters are ranked from highest to lowest by W, where the sum of all W equals 100

Clusters	N	W (%)	Qi		N	W (%)	Qi
Learning	1,883	11.2	0.43	Measurement	648	5.3	0.61
Motivation	1,514	10.1	0.47	Higher Education	1,207	4.3	0.68
Science Education	1,370	10.1	0.48	Cooperative Learning	554	4.2	0.79
Math Education	685	8.5	0.36	Child Behav. Development	1,534	3.4	0.71
Teacher Training	799	8.2	0.64	Language Teaching Methods	675	2.8	0.57
Cognitive Studies of Learning	790	6.8	0.59	Sociology of Education	1,715	2.5	0.71
Evaluation & Assessment	733	5.7	0.59	Child Cognitive Development	415	2.5	0.64
Educational Equality	1,800	5.4	0.67	Civic Education	417	2.1	0.79
Reading Education	1,140	5.3	0.43	Developmental Disabilities	667	1.5	0.82

On the other hand, the bottom five loosely connected clusters (i.e., “Language Teaching Methods”, “Sociology of Education”, “Child Cognitive Development”, “Civic Education”, and “Developmental Disabilities”) consist of multiple sub-clusters that reflect perspectives of related fields. In the cluster “Developmental Disabilities”, most sub-clusters are tied to the medical or psychology domain, as seen for example by their high use of the Diagnostic and Statistical Manual of Mental Disorders. Similarly, education is but one example of a political phenomenon for the “Sociology of Education” cluster, which also deals with general sociological matters such as globalization or colonialism. The “Language Teaching Methods” cluster also consists of multiple sub-clusters whose focus is not only on language teaching methods, but also on topics such as language policy or linguistic topics such as syntactic complexity in synchronous and asynchronous communication. Understanding such diverse issues are essential in designing and implementing various language teaching methods as well as other issues in education and points to the multi-disciplinary nature of educational research. According to our analysis, the extent to which different subfields in educational research draw on the references from other subfields in education or other fields (i.e. linguistics, sociology, or psychology) differs across clusters. Some rely on references more from subfields within education, while others rely on references from other fields as well as education.

In addition, there is a strong correlation (R2 = 0.58) between the clusters’ weighted degree (*W*) and internal modularity (*Qi*): Homogeneous clusters (low *Qi*) tend to be highly connected clusters (high W). We interpret this correlation as a consequence of the filtering of the scientific literature by our list of education journals, which, again, implicitly defines what “educational research” is. For some subfields, this definition allows to retrieve their main publications. Therefore, our analysis can recover the coherence of their “core knowledge” and these subfields will appear as homogeneous (quantified by a low *Qi*) and highly connected (i.e. “Learning”, “Motivation”, “Science Education”, “Math Education” and “Teacher Training”). On the contrary, for other subfields, the intersection of their main publications with our definition of educational research seems to break their (supposed, in this case) coherence (i.e. “Language Teaching Methods”, “Sociology of Education”, “Child Cognitive Development”, “Civic Education”, and “Developmental Disabilities”). These subfields appear as a juxtaposition of more loosely connected sub-clusters, some of them connected to the rest of education, most of them not. This is quantified by both a high *Qi* (loosely connected sub-clusters) and by a low *W* (most articles are not connected to education).

Summary and Conclusion

We have presented a scientometric analysis of education articles from the period 2000-2004 using the Scopus database. In the first section, we built a map of global educational research that consists of 18 research clusters or subfields. Each of these clusters represents a set of articles that are linked by shared references. The nature of the references varies across the clusters. Some clusters share a majority of theory based references, others a majority of methodological references and still others share a mixture of these reference types. One notable feature is the high visibility of consensus documents such as Standards for educational and psychological testing and the so-called Dearing Report on the Standards for educational and psychological testing. This type of publication does not play such a prominent role in other fields. For example, such consensus documents did not appear high on the core list of any of the clusters in our work with complex systems (Grauwin et al., 2012). On the other hand, how to teach and what to learn are issues that are determined not only by scientific principles of learning but also by what the society values as worthwhile knowledge, which is strongly influenced by historical and cultural contexts. The tensions that arise from the necessarily diverse perspectives are likely to require more consensus building efforts, which are reflected in consensus documents. Such consensus is informed by ongoing research, but also works as reference guide of educational research as is manifested in their high visibility.

Clusters differ also in terms of their connectivity to other clusters. In our analysis, certain clusters (i.e., "Learning", "Motivation", "Science Education", "Math Education", and "Teacher Training") are more connected than the others. These clusters and associated references, whether they are about theories or methods, play a more central role in organizing and giving coherence to educational research as a whole. In the case of the “Learning” cluster, the cluster with the highest connectivity, references related to sociocultural approach play a prominent role, including the top two cited references within the whole Education corpus (Vygotsky, 1978; Lave & Wenger, 1991), where these two references were also amongst those that most linked the clusters together. It can be said that sociocultural theory represents a main paradigm for this period. The connectivity of the clusters were highly correlated with internal heterogeneity of clusters so that less connected clusters tend to consist of multiple sub-clusters, some of which rely on references from fields outside of education. This demonstrates the multi-disciplinary nature of educational research and a need for integration efforts both within educational research and with the rest of the social sciences and other related fields. One of the future research agendas is to examine the map in relation to the Learning Sciences (LS) and research on Computer Supported Collaborative Learning (CSCL). The current paper represents groundwork that will guide us in the process of understanding not only where LS and CSCL are positioned in the map, but also how they have evolved over time, and the roles of LS and CSCL research in connecting educational research at large. In the end, the knowledge and insights gained in this process can also help us to understand the nature of collective knowledge building process called science.

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(1) Please write to seb.grauwin@gmail.com for supplementary materials that present the eighteen clusters in detail.

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Acknowledgments

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